Engaged by Design: Using Simulations to Promote Active Learning

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Abstract: We test our hypothesis that student in-class Internet actions reflect their engagement levels. We predict that an engaging learning environment will result in students performing a higher number of on-task Internet activities. To test our hypothesis, we compare student behaviors during two types of instructional episodes. Students participate in either a traditional, lecture-based lesson or an interactive simulation exercise. To measure student engagement levels, we develop a Classroom Behavioral Analysis System (CBAS) that records all student computer actions during the observed class periods. We then count and label these actions as on-task or off-task, depending on relevance to the classroom activity. We find that students attending the simulation class perform a significantly higher number of on-task actions. These findings support our hypothesis that engaging lessons result in higher levels of on-task Internet activities. Equally important, CBAS accurately reflects student engagement levels and is therefore a promising tool for studying engagement.

While engagement and learning seem innately linked, there is little research to quantify relations among classroom activity, student engagement, and positive learning outcomes (Fredricks, et. al., 2004). Part of the difficulty in determining this relation lies in the challenge of measuring student engagement. In a typical classroom situation, at any given time, some students are paying attention to varying degrees and others are not. It is difficult for instructors and researchers to determine the extent to which students are actually engaged with the classroom activities. Behavioral cues, such as students looking at the teacher, may provide some indication of engagement levels; however, students who appear to not be paying attention may be completely engaged and vice-versa. In a classroom context, it is difficult for instructors and researchers to accurately assess which students are engaged and which elements of the classroom activity encourage this engagement.

A potential solution to this problem rests in new technologies which offer us a window into student attention that has previously not been available. Previously problematic areas of learning and cognition, such as student attention levels within a classroom, can now be measured using emerging technologies to record and analyze student computer actions (Dickey, 2005; Zhang, et. al., 2005).

In this study, we developed a Classroom Behavioral Analysis System (CBAS) to measure student engagement levels as reflected by their on-task and off-task Internet actions. CBAS consisted of monitoring software that recorded all student computer actions performed during a class session, including keystroke activities, active applications, and website visits. At the end of each class session, CBAS reported this information as a log file that we studied to determine whether patterns existed in student engagement levels. This record of Internet activity could then be evaluated in light of the classroom instructional environment.

In order to validate CBAS as a tool for measuring engagement, our goal was to study whether student engagement levels were affected by lecture style. To measure these levels, we compared student computer behaviors in a writing class taught by lecture and a writing class taught by using an interactive simulation exercise. We used CBAS to record student Internet activities and then counted student off-task and on-task behaviors. We then compared these behaviors to determine whether student engagement levels, as measured by off-task and on-task Internet actions, were affected by the style of lecture delivery. If CBAS is a valid tool for measuring engagement, on-task behaviors should be higher and off-task behaviors lower in the simulation class than in the lecture class.

What mediates the notion that engagement improves learning?

Engagement is clearly a central component in many theories of academic learning. In fact, a general assumption of learning studies is that students learn more if they pay attention (Fredricks, et. al., 2004; McMahon & Portelli, 2004). Early studies define engagement in terms of interest (Dewey, 1913), effort (Meece & Blumenfeld, 1988), motivation (Pintrich & DeGroot, 1990; Skinner & Belmont, 1993), and time on task (Berliner, 1979, 1990; Lentz, 1998). In these studies, a conceptual correlation between engagement and positive learning outcomes is established by linking interest, for example, to active learning (Dewey, 1913; Schraw & Lehman, 2001), or effort to goal achievement (Brophy, et. al., 1983; Meece & Blumenfeld, 1988). Research on active engagement consistently shows that when students are focused on a task, they are more likely to apply effort toward their learning experience (Ames 1992; Brophy, et al., 1983).

A trend in recent research is to extend our existing understanding of motivation by studying the cognitive strategies that result from its varying levels (Pintrich, 2002; Pressley, 1986; Winne, 1992). Metacognitive control, which is evident in students' ability to not only know what to do in a learning situation (cognitive strategies), but when to do it, is measured by self-efficacy cues, self-regulation, and goal setting. Pressley (1986) and Winne (1992) argue that metacognitive control is teachable. Current studies of classroom engagement consistently find that the classroom environment, including the lesson plan and lecture delivery style, can affect students' practice of metacognitive control (Dickey, 2005; Winne, 2006). Importantly, students demonstrating cognitive strategies such as task-mastery goals report higher levels of engagement and perform better on assigned tasks (Ames & Archer, 1988; Meece, 1988). Students who believe they are capable of performing assigned tasks (self-efficacy belief) also demonstrate high academic performance (Ames & Archer, 1983; Schunk, 1989, 1991; Zimmerman & Martinez-Pons, 1990).

Research on self-efficacy shows correlations between self-efficacy beliefs and active learning strategies, as well as self-efficacy beliefs and improved performance on achievement tests (Ames, 1992; Pintrich & DeGroot, 1990; Schunk, 1985, 1989; Zimmerman & Martinez-Pons, 1990). Students' self-efficacy beliefs reflect how well they believe they will perform on a task. According to Mayer (2003), these beliefs come from four sources within the student's classroom experience: "interpreting one's own performance, interpreting the performance of others, interpreting others' expressions of your capabilities, and interpreting one's physiological state" (p. 470). While factors such as experience and aptitude play a role in the self-efficacy beliefs students bring to the classroom, Ames (1992) asserts that self-efficacy beliefs are also formed during the instructional episode. Since students revise their self-efficacy beliefs based on interpretations of peer and teacher interactions, the presentation of information during the lesson is essential to encouraging high self-efficacy and therefore active engagement in the learning process (Zimmerman & Martinez-Pons, 1990).

A basic tenet of these cognitive theories of learning and instruction is that students learn more deeply when they are engaged in active learning than when they are passive recipients of information (Grabinger, 1996; Mayer, 2003; Pearce, 2005). Active learning occurs when a learner engages in active cognitive processing during learning, such as attending to relevant information, organizing the selected information into a coherent cognitive structure, and integrating the information with existing knowledge (Mayer, 2001, 2003). Active learning takes place in an environment where a student is not a passive listener but is instead an active participant in his/her learning experience (Gee, 2003; Jonassen, 1996, 1999).

How can new technologies be used to study student engagement?

Computer lab settings provide fresh opportunities for measuring classroom behaviors because students use the computer for both course-relevant and recreational activities. In this setting, technologies can be used to collect student behavior data such as applications used, time spent using each application, Internet activities, frequency of attention shifts within program use, and keystrokes. These computer actions offer a window into the cognitive interplay between student and computer. Computer actions show where students focus their attention during the lecture, the duration of this focus, and when this focus shifts.

In light of the new measurement opportunities made possible by emerging technologies, it makes sense to return to Berliner's research (1987, 1990) on student engagement as measured by time on task. In Berliner's (1979) study of engagement, he assumes a causal relationship between "engaged time" and variability in academic achievement. In our study, we applied Berliner's concept of time on task to measure student engagement levels. We used CBAS to record student computer actions during a class session and then coded the actions as on-task or off-task. We specifically focused on Internet actions because they provide a clear record of on-task use, which for our study included using the course website, reference pages, or online writing labs. In contrast, we defined off-task use as visiting websites with non-course relevant materials such as sports, gambling, or banking websites. We hypothesize that student computer actions, specifically, their Internet use, will reflect their engagement levels.

Method

To test the validity of our measurement tool, we assessed student levels under two conditions. In our first study, we measured student attention during a standard instructional episode that was not specifically designed to be engaging. We refer to this as the *no simulation* condition because a conventional lecture format was used instead of an interactive simulation exercise. We predict that in this no simulation condition, student engagement levels will be low, reflected in frequent off-task Internet actions and minimal on-task Internet actions.

In our second study, we assessed student engagement levels as measured by off-task and on-task Internet actions during an instructional episode that we specifically designed to be engaging. Since we used an interactive simulation exercise in this study, we refer to it as the *simulation* condition. Applying engagement research findings to lesson plan development should result in instructional activities that enhance student engagement levels. While in the first study, the lesson was lecture-driven and instructor-centered with minimal structure for using the computer as a resource, in our second study, we designed a student-centered interactive activity to promote active participation in the lesson. Unlike the no simulation condition, in the simulation condition the activity centered on using the computer as a resource to complete the assignment. We predict that in the simulation condition, on-task Internet actions will be high and off-task Internet actions will be minimal. We predict that this type of lesson design will result in the participants using the classroom computers as learning resources, rather than recreational tools. Testing these predictions provides a means of testing the validity of the Classroom Behavioral Analysis System (CBAS), as a tool for capturing learning engagement.

Participants and Design

One hundred thirty-nine students enrolled in freshman composition courses at the University of California, Santa Barbara participated in our study. Participants were enrolled in seven sections of a freshman composition course taught during the 2004 – 2005 academic year. All students enrolled in the seven freshman composition courses were given the option to participate. Out of 144 students, 139 volunteered for the study and five chose not to participate. Thirty-two participants in two intact classes were given the no simulation lectures and 107 participants in five intact classes were given the simulation exercise. All consented to the recording of their in-class computer activities. Our design is quasi-experimental because intact classes (rather than individual learners) were assigned to the treatments.

Our dependent variable was student engagement measured by off-task and on-task Internet activities. Off-task Internet activities were operationalized as website visits that were not part of the assigned class activity, for example if a participant visited a banking or sports news website (e.g., Wells Fargo or ESPN), we considered this activity to be off-task. On-task Internet activities included website visits that related to the assigned class activity, such as a word definition search or the use of an online writing lab (e.g. Purdue's OWL).

The classroom used in the study held 25 computers arranged in five front-to-back rows. The classroom was equipped with Dell Pentium III computers that were identically configured to include Internet access, web browsers, Microsoft Office, and graphic development software. CBAS was installed on each computer and recorded keystroke activities, active applications, and URL visits. A video camera positioned in the back of the classroom recorded observable classroom activity, including the instructor's lecture and participant behavior.

Procedure
Participants were observed during a single 110-minute instructional episode. As participants entered the classroom, they logged into a computer of their choice. CBAS recorded every computer action during the class period, beginning with login and ending with logout. Once participants logged out at the end of class, CBAS generated a log file containing all keystroke, application use, and URL information for each participant as well as a comprehensive file for the entire cohort.

No simulation condition. The instructor used a conventional, lecture-style format for the first fifteen minutes of class and then directed the students to use the additional class time to revise their paper drafts. The focus of the lesson was on revision, so the instructor began her lecture by describing a personal experience in which she needed to learn a new skill and then introduced techniques for revision. Next, she reviewed the requirements of the assignment and directed participants to use the computers to revise their drafts. For the remaining hour of the class period, participants worked individually on their papers.

Simulation exercise. A simulation exercise is a learning activity that immerses students in a real-world environment. In this study, we developed a simulation exercise consisting of a website that detailed a mining accident and prompted participants to write a rescue plan. The activity took place in real time, and required participants to submit a report to the instructor at the end of the exercise. Participants worked collaboratively in groups while the instructor participated directly in the learning activity by role-playing and responding to student requests for information and support.

Figure 1 shows the online entry and resource pages used in our simulation exercise. All of the events described on the website were designed to occur within the timeframe of the class. The website contained four sections, including an overview, a timeline, a list of personnel and resources, and pertinent data. Diagrams, maps, and photos on each page illustrated the accident and the plight of the miners. The Personnel and Resources section contained links to actual search and rescue teams, such as the Mono County Sheriff website and the US Navy Explosive Ordnance Disposal Team (see Figure 1). The Data section provided depth measurements, temperature, and other necessary information about the mines and miners, and in many cases prompted the participants to perform their own calculations.

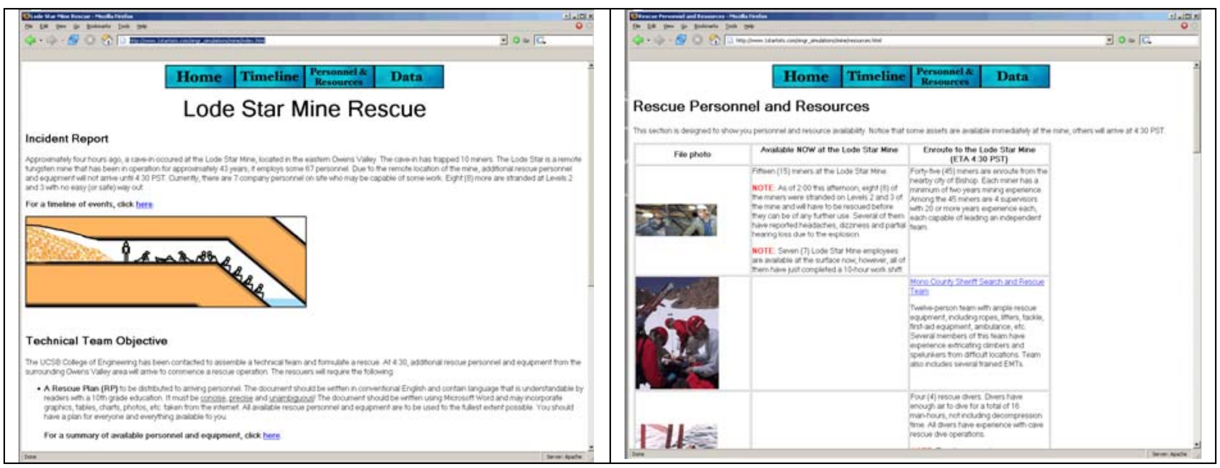

Figure 1: Entry page for simulation exercise and sample resource page,

In each class section, the instructor began by describing the mining accident and providing an overview of the class activity. In some cases, the instructor described how simulation exercises worked (e.g. occur in real time, address real world situations), but in others, the instructor immediately began role playing by announcing the mining accident and explaining the urgent need for rescue plans.

Regardless of the initial approach, all instructors directed participants to the mining simulation website, described the rescue plan assignment, and divided the class into groups of four or five. Participants were required to identify critical tasks and assign duties within their groups. During each class, the instructor interrupted the activity six times to post a “Situation Report,” which introduced new variables by providing updates about the health of the miners, announcing that resources had been added or taken away, or stating that the timeline had been shortened or extended. At the end of class, participants uploaded their group rescue plans to a folder that all class members were able to access. The instructors ended their classes with a group discussion about the feasibility, clarity, and depth of each rescue plan and asked the participants to evaluate their experience of working as a team to write a collaborative document.

Results

Scoring

The action logs generated by CBAS reported all keystroke actions, URL visits, and active window entries for each participant (as shown in the sample log file in Figure 2). Each instance of Microsoft Internet Explorer or Mozilla Firefox that appeared as an active window entry was counted and labeled as either an off-task or on-task Internet action.

COMP	EXE_FILE	PARENT_WIN	ACTIVE_WIN	OPEN_URL	START_DATE	START_TIME	DURATION	KEYSTROKES
MESA-4	C:\Apps\G	Rescue Plan for	Rescue Plan for Lode Star Mine Rescue.doc - Micr		4/5/2005	14:44:19	0:00:14	[DEL] [BACK] [DEL] [DEL] [BACK] [BA
MESA-4	C:\Apps\G	Rescue Plan for	Rescue Plan for Lode Star Mine Rescue.doc - Micr		4/5/2005	14:44:34	0:00:21	
MESA-4	C:\Apps\G	Rescue Plan for	Rescue Plan for Lode Star Mine Rescue.doc - Micr		4/5/2005	14:44:57	0:01:47	15 [SPACE] [SHIFT]Mint [BACK]ers [SP
MESA-4	C:\Apps\G	Rescue Plan for	Rescue Plan for Lode Star Mine Rescue.doc - Micr		4/5/2005	14:46:45	0:00:19	7 [SPACE] [SHIFT]N [BACK] [SHIFT]Mir
MESA-4	C:\Apps\G	Rescue Plan for	Rescue Plan for Lode Star Mine Rescue.doc - Micr		4/5/2005	14:47:06	0:00:09	[BACK] [ENTER]
MESA-4	C:\Apps\In	Rescue Personn	Rescue Personnel a	http://www.1startists.com/engr_	4/5/2005	14:47:15	0:00:05	
MESA-4	C:\Apps\G	Rescue Plan for	Rescue Plan for Lode Star Mine Rescue.doc - Micr		4/5/2005	14:47:21	0:00:12	[SHIFT]Rock [SPACE] [SHIFT]Bolts [BA
MESA-4	C:\Apps\G	Rescue Plan for	Rescue Plan for Lode Star Mine Rescue.doc - Micr		4/5/2005	14:47:34	0:00:24	stta [BACK] [BACK]abalix [BACK]ze [SF
MESA-4	C:\Apps\G	Rescue Plan for	Rescue Plan for Lode Star Mine Rescue.doc - Micr		4/5/2005	14:48:01	0:00:29	

Figure 2: Sample log file generated by CBAS,

Website addresses (URLs) that were not part of the assigned class activity were labeled as off-task. For example, URLs containing terms such as “poker” and “NBA” were considered off-task. We used these off-task entries to compile a list of 93 unique search terms and used these search terms to calculate the total number of off-task Internet actions recorded in the log files. Examples include: AIM, poker, Ebay, Facebook, Ebaum, games, Hotmail, IMDB, MTV, BBC, ESPN, or Travelzoo.

URLs were labeled as on-task if they were assigned as part of the class activity. We used these on-task entries to compile a list of 47 unique search terms. We then used these unique search terms to calculate the total number of on-task Internet actions. Examples include: dictionary, library, OWL, research, thesaurus, and .edu.

How engaged are students during a lecture taught using traditional methods?

The focus of our first study was to determine whether CBAS would reflect low student engagement levels in a lesson not specifically designed to be engaging. In this first study, the lesson was taught using a traditional lecture-style format and did not use a simulation exercise. We predicted that student engagement levels would be low, resulting in frequent off-task behaviors and minimal on-task behaviors. We further predicted that CBAS, which recorded keystroke actions, active window records, and URL visit data, would reflect these low levels of student engagement by recording high levels of off-task behaviors.

In the no simulation condition, participants performed significantly more off-task Internet actions (M =34.31, SD = 28.03) than on-task Internet actions (M = 11.72, SD = 11.33), $t(31) = 4.35$, $p < .001$, two-tailed. Off-task Internet actions accounted for 79% of the cohort’s total Internet use. This data shows that a lesson taught using a traditional lecture-style format that did not apply engagement research findings resulted in low student engagement levels, as reflected by high off-task Internet actions.

How attentive are students during a lecture taught using a simulation exercise?

In our second study, we tested whether CBAS would accurately reflect student engagement levels during an instructional episode designed to be engaging. In this study, we predicted that student engagement levels, as measured by on-task Internet actions, would be high given the interactive nature of our simulation exercise.

Analyses of variance (ANOVAs) revealed that the action counts for each group did not differ significantly from any of the other groups *f*(4, 102), *p*=.65. Therefore, we combined the five classes into one large group labeled the *simulation group*.

In the simulation condition, participants performed significantly more on-task Internet actions (*M* = 27.71, *SD* = 19.11) than off-task Internet actions (*M* = 3.79, *SD* = 5.89). Off-task Internet actions accounted for 9% of this cohort's total Internet use *t*(106) = 12.55, *p* < .001. This data shows that using an interactive simulation exercise resulted in increased student engagement levels, as reflected by high on-task Internet actions.

Table 1 Mean number and standard deviations of total Internet actions, on-task, and off-task Internet actions by participants in the no simulation and simulation conditions,

	Total Internet actions		**On-task Internet actions**		**Off-task Internet actions**	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
No Simulation	43.38	36.46	11.72	11.33	34.31	28.02
Simulation	40.34	24.8	27.71	19.11	3.79	5.89

Are student engagement levels affected by instructional style?
In these studies, we tested our hypothesis that student engagement levels can be increased by applying findings from engagement research to lesson plan design. We also tested CBAS to determine whether it would reflect student engagement levels during instructional episodes designed to be high or low in engagement. Table 1 shows total Internet actions, on-task Internet actions, and off-task Internet actions for each condition. Total Internet actions per user did not differ significantly between the simulation condition (*M* = 40.34, *SD* = 24.8) and the no simulation condition (*M* = 43.38, *SD* = 36.46), indicating that students in both groups were equally active in their Internet use, *t*(137) = -.541, *p* = .589. This finding is important when considering the significant difference in the proportion of off-task and on-task Internet actions recorded for the two groups.

We predicted that off-task Internet actions would be high in the no simulation condition and low when a simulation was used. As predicted, the simulation group performed significantly fewer off-task Internet actions (*M* = 3.79, *SD* = 5.89) than the no simulation group (*M* = 34.31, *SD* = 28.03), *t*(137) = 10.59, *p* < .001. Since off-task Internet actions reflect low levels of attention, students in the no simulation condition appear to have lower engagement levels than students in the simulation condition. These results support our hypothesis that it is possible to specifically design an instructional episode that heightens student engagement levels. Additionally, this data validates that CBAS accurately reflected student engagement levels since it recorded high levels of off-task Internet actions in the no simulation condition and low levels of off-task Internet actions in the simulation condition.

Also, as predicted, the simulation condition produced significantly more on-task Internet actions (*M* = 27.71, *SD* 19.11) than the no simulation condition (*M* = 11.72, *SD* 11.33), *t*(137) = 4.50, *p* < .001. While the mean number of total Internet actions per user was similar in both groups, this significant difference in on-task Internet actions further supports our hypothesis that an interactive simulation exercise will result in increased engagement levels, as reflected by a higher number of on-task actions. These findings also validate CBAS as an effective tool for measuring engagement during learning.

The proportion of off-task Internet actions in the simulation condition accounted for 9% of the students' total Internet use, compared with 79% of the students' Internet use in the no simulation condition. A t-test showed that these numbers were significantly different, *t*(137) = -.5.19, *p* < .001. This high difference between the two conditions further supports our hypothesis that a lesson specifically designed to be engaging will result in a lower number of off-task Internet actions.

To compare overall Internet use for both groups, we subtracted on-task Internet actions from off-task Internet actions for each participant. Overall Internet activity types differed significantly, with the simulation group performing more on-task actions and the no simulation group performing more off-task actions, $t(137) = 10.37$, $p < .001$. Using Cohen's d, we found a 1.57 standard deviation difference in off-task and on-task Internet actions, a large effect size, which further indicates that simulation exercises result in higher on-task Internet use.

Conclusions

Summary

In this study, we developed CBAS to measure student engagement levels in computer-equipped classrooms. Our findings provide support for the validity of this tool. First, CBAS recorded high levels of student engagement in the simulation condition demonstrated by significantly low levels of off-task Internet actions. Second, it proved similarly effective by measuring low levels of engagement with the class activity in the no simulation condition that were reflected by a high number of off-task Internet actions. CBAS proved to be a promising measure of student engagement that can be used in future studies to assess whether other classroom technologies affect student attention levels.

Limitations and future directions

This study provides an example of effectively applying emerging technologies to previously problematic areas of study (Fredricks, et. al., 2004; McMahon & Portelli, 2004). To further test the potential of CBAS, future studies should explore the relationship between the measured engagement levels and academic performance. In our study, different instructors taught in the two conditions; future studies could use the same instructor for both conditions to reduce the possibility of an instructor effect. In the simulation condition, participants worked in groups, whereas in the no simulation condition, participants worked alone. By consistently requiring group work in both conditions, we could have better studied this variable. While this study did not address differences in age and gender among participants, these differences are also worthy of further research.

Practical implications

One of the most challenging aspects of teaching is maintaining student engagement levels. In our study, we found that it is possible to encourage high levels of student engagement by using a simulation exercise. The high levels of student on-task actions in the simulation classes indicate that directed interactive activities promote high levels of student engagement.

What, then, causes students to pay attention? In our study, participants appeared more attentive during the simulation exercise than in the traditionally taught lecture. We incorporated several strategies to promote active learning in the simulation condition. Strategies included assigning collaborative work with an in-class deliverable, requiring students to seek information beyond the confines of the classroom, and supporting the formation of learning connections by providing resources and encouraging students to develop their own understandings of the material presented. We need to conduct further studies to determine exactly which combination of strategies resulted in increased engagement levels.

Theoretical implications

Our study addresses the potentially distracting nature of Internet-connected computers in the classroom. While the participants in the no simulation condition clearly demonstrated low levels of attention reflected in low on-task Internet use, the participants in the simulation condition used the computer as a resource, rather than a recreational tool and demonstrated correspondingly high levels of on-task Internet actions. These findings support our hypothesis that, while a computer can be potentially distracting, creating immersive activities can maximize its effectiveness as a learning tool and classroom resource.

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